General

Guideline Title

ACR Appropriateness Criteria® abdominal aortic aneurysm: interventional planning and follow-up.

Bibliographic Source(s)

Francois CJ, Kramer JH, Rybicki FJ, Ray CE Jr, Bandyk DF, Burke CT, Dill KE, Gerhard-Herman MD, Hanley M, Hohenwalter EJ, Mohler ER III, Rochon PJ, Schenker MP, Expert Panel on Vascular Imaging and Interventional Radiology. ACR Appropriateness CriteriaÂ® abdominal aortic aneurysm: interventional planning and follow-up. [online publication]. Reston (VA): American College of Radiology (ACR); 2012. 8 p. [71 references]

Guideline Status

This is the current release of the guideline.

This guideline updates a previous version: Lin M, Narra VR, Rybicki FJ, Funaki BS, Burke CT, Fan CM, Gerhard-Herman MD, Kim HS, Koss SA, Mansour MA, Owens CA, Ray CE Jr, Saad WEA, Expert Panel on Vascular Imaging and Interventional Radiology. ACR Appropriateness Criteria® abdominal aortic aneurysm: interventional planning and follow-up. [online publication]. Reston (VA): American College of Radiology (ACR); 2010. 8 p.

Recommendations

Major Recommendations

ACR Appropriateness Criteria®

Clinical Condition: Abdominal Aortic Aneurysm: Interventional Planning and Follow-up

Variant 1: Planning for pre-endovascular repair (EVAR) or open repair of AAA.

Radiologic Procedure	Rating	Comments	RRL*
CTA abdomen and pelvis with contrast	9	For evaluation of known AAA without thoracic aortic involvement. Noncontrast sequence is not necessary for interventional planning.	☢☢☢☢☢
CTA chest abdomen pelvis with contrast	8	Useful for patients with suspected AAA but no prior workup of the thoracic aorta. Study of choice for workup of suprarenal AAA or thoracoabdominal aneurysm.	☢☢☢☢☢
CTA abdomen and pelvis without and with contrast	1	Usually not appropriate	☢☢☢☢

Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate

*Relative Radiation Level

Radiologic Procedure	Rating	Comments	RRL*
contrast		included. Appropriate for patients with contraindication to iodinated contrast. Occasionally depicts density differences between the blood pool and aortic wall/mural thrombus. Otherwise, further luminal assessment with MRI, US, or DSA would be preferred.	
MRA abdomen and pelvis without and with contrast	6	Alternative to CTA in patients with known AAA not involving the thoracic aorta and in whom iodinated contrast is contraindicated. See statement regarding contrast in text under "Anticipated Exceptions."	O
CT chest abdomen pelvis without contrast	5	Appropriate for patients with contraindication to iodinated contrast. Occasionally depicts density differences between the blood pool and aortic wall/mural thrombus. Otherwise, further luminal assessment with MRI, US or DSA would be preferred.	☢☢☢☢
Digital subtraction angiography (DSA) aorta	5	May be appropriate in select cases including patients who require pre-operative embolization of branch vessels or those requiring further characterization of the aortic lumen with an alternative contrast agent (such as CO_2) or intravascular US.	☢☢☢
MRA chest abdomen pelvis without and with contrast	5	Alternative to CTA in patients with contraindication to iodinated contrast who have had no prior evaluation of thoracic aorta. See statement regarding contrast in text under "Anticipated Exceptions."	O
MRA chest abdomen pelvis without contrast	4	Appropriate for patients with severe renal dysfunction.	O
MRA abdomen and pelvis without contrast	4	Appropriate for patients with severe renal dysfunction. At physician's discretion, chest may not be included.	O
US aorta abdomen with Doppler	3	Useful screening tool, but insufficient for AAA treatment planning. May be used in tandem with DSA in the absence of cross-sectional imaging, or as an adjunct to noncontrast CT for luminal evaluation.	O
X-ray chest abdomen pelvis	1		☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Variant 2: Follow-up for post-endovascular repair (EVAR) or open repair of AAA.

Radiologic Procedure	Rating	Comments	RRL*
CTA abdomen and pelvis with contrast	9	Method of choice.	☢☢☢☢☢
MRA abdomen and pelvis without and with contrast	7	Appropriate alternative to CTA, but less accurate for assessing endograft metallic components. Effectiveness depends on composition of endoprosthesis. 3D contrast-enhanced MRA and time-resolved MRA are highly sensitive to endoleaks. See statement regarding contrast in text under "Anticipated Exceptions."	O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative**

Radiologic Procedure	Rating	Comments	RRL*
CT abdomen and pelvis without contrast	6	Appropriate for patients with MR-incompatible devices or contraindication to iodinated contrast. Provides temporal information regarding sac morphology with reduced contrast exposure and radiation burden. US is a useful adjunctive tool for endoleak detection.	☢☢☢☢
Digital subtraction angiography (DSA) aorta	6	Selectively useful for characterization and treatment of endoleaks type I and III.	☢☢☢
MRA abdomen and pelvis without contrast	5	Selectively useful for assessment of renal or mesenteric vasculature in patients with contraindication to iodinated contrast.	O
US aorta abdomen with Doppler	5	Important adjunct to noncontrast CT for endoleak detection. May be useful in endoleak characterization.	O
X-ray abdomen and pelvis	4	Provides detailed survey for structural integrity of the metallic components of the endograft but not the nonmetallic components. Particularly useful with tortuous anatomy. However, inadequate as a stand-alone follow-up modality.	☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Note: Abbreviations used in the tables are listed at the end of the "Major Recommendations" field.

Summary of Literature Review

Introduction/Background

In 1991, a group of investigators reported successful deployment of an endoluminal stent graft within the aorta via a transfemoral approach. It permanently transformed the landscape of abdominal aortic aneurysm (AAA) management and therapy. Previous treatment options were limited to expectant management combining medical control of blood pressure with close imaging surveillance, versus open surgical repair. Due to significant perioperative morbidity of open repair, the exact point of transition to surgical intervention varied on an individual basis, but relatively well-defined guidelines were in place to help direct decision-making and led to the implementation of guidelines for screening for AAA. These guidelines were developed based on the patient's health status, comorbidities, the aneurysm's absolute size (>5.5 cm) and rate of change (>1 cm/year), and other signs indicating impending rupture. The arrival of the EVAR (endovascular aneurysm repair) technique introduced new variables to managing AAAs.

Multiple studies have shown significantly decreased length of hospital stay and decreased perioperative morbidity with this procedure compared to open repair. Though increasingly replaced by EVAR, open repair is still performed in patients with unsuitable aneurysm morphology for EVAR and in those with failed EVAR. For patients who present de novo for treatment of AAA without any prior imaging available, the entire aorta, including the thoracic portion, should be assessed to fully characterize the aneurysm and to exclude a concomitant thoracic aortic aneurysm. Preoperative imaging for open repair of AAA has one main focus: to determine the need for surgery based on aneurysm size, extent, and, if borderline in size, rate of growth. Additional information on anatomical variants can also be helpful in guiding appropriate treatment and preventing unexpected complications at time of repair.

EVAR, in particular, requires accurate preoperative imaging evaluation for appropriate patient selection based on aneurysm morphology and access vessel size and patency. Paramount considerations in evaluating an AAA for EVAR lie in the morphology of the proximal neck, which for infrarenal AAA is defined as that segment of aorta between the most caudal renal artery and the proximal boundary of the aneurysm. An unfavorable neck anatomy, based on its diameter, length, angulation, morphology, and presence of calcification, was the most frequent cause of exclusion from EVAR in the past. For traditional EVAR, a neck size of >10-15 mm in length and <30 mm in diameter was required to provide an adequate seal proximally. However, in recent years, new devices have become available which either feature an uncovered proximal part which allows for placing the stent directly at the origin of aortic branches or possess ready-made vessel origins, e.g., for the renal and mesenteric arteries. These latter devices are known as branched or fenestrated devices. The uncovered, branched and fenestrated stents may be especially favorable in women because they are less likely to have neck and iliac diameters sufficient for traditional EVAR. However, while not an absolute contraindication to EVAR, mural thrombus and atherosclerotic calcification covering more than 90 degrees of the circumference of the aortic

diameter in the proximal neck is associated with a higher risk for type I endoleak and stent-graft migration. The distal landing zone is usually in the common iliac artery. With the new generation of devices, common iliac artery diameters of ≤20 mm can be considered for EVAR. The minimal external iliac artery intraluminal diameter should be ≥7 mm to safely accept delivery sheaths.

The advantages conferred by EVAR come at a cost of lifelong imaging surveillance, due to higher rate of complications (which can occur any time after the procedure) requiring reintervention compared to open repair. Some complications of EVAR include stent graft migration, kinking, infection, thrombosis, and renal dysfunction. The most important complication to detect is continued aneurysm expansion leading to eventual rupture, which can occur even after successful EVAR. The most common complication of EVAR is endoleak formation, which may contribute to aneurysm sac enlargement and rupture. There are different classifications for endoleaks occurring after EVAR, with three different types occurring most commonly. Appropriate classification is crucial for subsequent management, and should be clarified when possible. Although EVAR is safe with a low mortality rate from AAA, the possibility of complications and need for reintervention remains high, requiring life-long monitoring.

The ultimate goal of endovascular therapy is to prevent aneurysm rupture, and follow-up imaging is the most useful tool to evaluate outcome, in addition to monitoring complications. Success is presumed to be reflected by aneurysm size stability or regression over time, with decreasing size of the AAA believed to indicate low risk of rupture. All available imaging modalities have been investigated over time for their efficacy in post-EVAR follow-up. According to Society of Interventional Radiology guidelines, the imaging modality of choice should allow at least 1) measurement of aortic aneurysm diameter, 2) detection and classification of endoleaks, and 3) detection of morphologic details of the stent grafts. Imaging modalities should be assessed by their effectiveness in satisfying these three parameters, as well as their respective safety profiles, including use of ionizing radiation and potentially nephrotoxic contrast agents.

Computed Tomography Angiography

Computed tomography angiography (CTA), with its superior spatial resolution, faster patient throughput, and wide availability, has gained wide acceptance as the gold standard for pre-EVAR evaluation as well as post-EVAR and post-open-repair imaging surveillance. Its disadvantages include the use of ionizing radiation and contrast medium, and its higher cost compared to ultrasound (US).

While not necessary in the early postoperative period, it is recommended that CT imaging be performed within 5 years of open repair of AAA to detect aneurysmal degeneration involving the pararenal aorta, iliac arteries, graft, or anastomotic sites. Following EVAR, the most widely used surveillance regimen includes multiphasic contrast-enhanced CT scans at 1, 6, and 12 months and yearly thereafter. In the absence of adverse outcomes at early post-EVAR imaging, the intensity and frequency of the surveillance program may be modulated accordingly. Compared to conventional catheter angiography, CTA may have higher sensitivity in detecting endoleaks after EVAR. Compared to US, CTA is more accurate in measuring aneurysms and more sensitive for endoleak detection.

CT imaging may be performed as a single arterial phase, biphasic study (noncontrast and arterial or arterial and delayed phases) or as a triphasic study (noncontrast, arterial and delayed phases). To reduce the cumulative radiation dose, there are proponents of eliminating the arterial phase, while others suggest eliminating the delayed phase. One author has suggested including the nonenhanced sequence only at the initial 1-month follow-up. There are also recent reports of acquiring images only in the delayed phase with dual-energy CT, with reconstruction of virtual nonenhanced images. Determining the optimal dose-efficient CT technique is clearly a work in progress, and it will only be elucidated with more experience.

Maximum aneurysm diameter was used initially in the majority of studies monitoring EVAR results. This method has been shown to be unreliable due to substantial interobserver variability. Volume analysis has since been recognized as a more robust method for determining success of the procedure, and for providing management guidelines. In an effort to reduce radiation and contrast exposure, some authors have proposed using serial volumetric analysis of aortic aneurysms with nonenhanced CT as the screening test for post-EVAR follow-up. Volume discrepancy due to interoperator variability has been previously demonstrated to be less than 2% when the procedure is performed by experienced personnel. In patients in whom contrast agents are contraindicated, serial volume measurements of the nonenhanced aortic aneurysm provides valuable information in guiding management.

Catheter Angiography

Catheter angiography can accurately assess aortic side branch patency, which is crucial for deployment of conventional and branched or fenestrated endografts. However, it fails to demonstrate mural thrombus that compromises diameter measurement and landing zone assessment, and is therefore not an adequate examination for preoperative evaluation for the EVAR procedure. Due to its relatively invasive nature, catheter angiography is also not commonly used as the first-line modality for post-EVAR surveillance. In addition, this technique imparts ionizing radiation and uses iodinated contrast. Though less sensitive than CTA in detecting endoleaks, digital subtraction angiography (DSA) is more accurate than conventional CTA in classifying endoleaks because the direction of blood flow in or out of the aneurysm sac can be assessed by DSA. One study showed only 86% agreement in endoleak classification between DSA and CTA, and subsequent correct classification of endoleaks by DSA significantly improved patient management. It stands to reason that catheter angiography may be best used as a second-line imaging modality in

post-EVAR patients, playing a vital role in endoleak classification and reintervention.

Magnetic Resonance Angiography (MRA)

The advantage of magnetic resonance imaging/angiography (MRI/MRA) relative to CT/CTA is its lack of ionizing radiation exposure. Until recently, MR contrast agents were felt to have low nephrotoxicity, and therefore traditionally regarded as a favorable feature of MRI. However, this concept has since come under scrutiny as some gadolinium-based contrast agents have been linked to nephrogenic systemic fibrosis. Hence, evaluation of renal function before contrast is used is recommended. The disadvantages of MRI/MRA include its cost, relative inaccessibility, long scanning time, patient claustrophobia, decreased spatial resolution, and contraindication in patients with cardiac pacemakers. Additionally, susceptibility artifact from the stent graft presents a diagnostic challenge for assessing device integrity, and may mimic graft stenosis.

For the purpose of pre-EVAR planning, T1-weighted spin-echo (black blood) images and flow-based methods such as time-of-flight (TOF) or phase contrast (white blood imaging) provide adequate details regarding aneurysm morphology and relevant vascular anatomy. However, these techniques are limited by low spatial resolution and signal-to-noise ratio, and therefore are suboptimal for evaluating small vessel lesions or small side branches. Furthermore, the flowing blood techniques are susceptible to flow artifacts that may overestimate stenoses or even falsely demonstrate an occlusion. To overcome these limitations, contrast-enhanced MRA (CE-MRA) should be added to conventional T1- and T2-weighted spin echo sequences. CE-MRA is much less susceptible to flow and blooming artifacts and has a high signal-to-noise ratio for evaluating small vessels and structural details. The effectiveness of CE-MRA has been found to be comparable to that of CTA in assessing the suitability of aneurysms for EVAR.

When considering using MRI for post-EVAR surveillance, structural contents and orientation of the stent graft are important considerations. Stents are usually made of nitinol, elgiloy, or stainless steel. Nitinol is an alloy of nickel and titanium which causes relatively few artifacts on MRI, and it allows for visualization of the stent lumen and adjacent structures. Elgiloy is an alloy of cobalt, chromium, and nickel which may obscure the stent lumen while allowing visualization of the adjacent structures. Patients with nitinol stents are the best candidates for MRA, and those with stainless steel or elgiloy stents may experience significant artifacts that compromise visualization of the stent lumen and limit morphological resolution of stent wall. However, artifacts may arise even with nitinol stents secondary to stent geometry.

MRA of the post-EVAR aorta shares multiple features with CTA. MR images may be reformatted three-dimensionally for volume or diameter measurements. In patients with nitinol stents, aortic diameter measurements for MRA have been shown to be as reliable as those obtained with CTA. For detection and sizing of endoleak, MRA is at least as sensitive as, and probably better than, CTA. Indeed, the higher rate of endoleak detection seen with MRA in cases of negative CTA may shed light on the phenomenon of endotension. Also, time-resolved MRA has recently been used to characterize endoleaks. It was found to provide relevant information regarding contrast dynamics and direction of flow of endoleaks, and it shows promise in replacing DSA as an effective, noninvasive method for endoleak characterization.

Color Duplex Ultrasound

Color duplex US is a viable imaging solution for post-EVAR follow-up. It is convenient, noninvasive, and relatively inexpensive, and it has a favorable safety profile. For these reasons, some authors advocate performing color duplex US for post-EVAR screening. Although excellent correlation between AAA diameter measurements on CT and US has been noted, there is fairly uniform agreement that US underestimates aneurysm diameter by approximately 2 mm. For detection of endoleak formation, color-coded duplex US has high specificity but limited sensitivity, reported to be 91% to 93% and 66% to 69%, respectively, in two large meta-analysis studies. Moreover, image quality of US is highly dependent on operator experience, patient preparation, and body habitus.

Not unexpectedly, published results regarding the accuracy of duplex US in post-EVAR follow-up have been varied. Nevertheless, real-time US does offer the distinct advantage of determining endoleak flow direction, which is useful for guiding management. Spectral waveform analysis of intrasac reperfusion also has prognostic value, where type II endoleaks with bidirectional flow and low flow velocities have been associated with spontaneous closure. In patients with absolute contraindications to iodinated contrast, whether due to severe renal impairment or to life-threatening contrast allergy, color duplex US becomes an important adjunct to nonenhanced CT. Furthermore, infusion of microbubbles increases the diagnostic accuracy of US for endoleak detection, and it has the potential to replace CTA as the primary surveillance modality.

Radiography

Radiographs were previously considered to be a useful adjunct to CT for detecting structural changes in the stent graft. This examination cannot be used as a stand-alone study, as it clearly does not assess for changes in the size of the excluded aneurysm sac or for the presence of endoleak, and therefore does not meet guideline criteria outlined by the Society of Interventional Radiology. Despite its limitations, anterior and lateral radiographs have been shown to be useful for detecting stent migration or modular separation of the stent graft, and oblique films can detect wire fractures. However, three-dimensional postprocessed CTA images can provide this information, in addition to detecting endoleak formation and changes in aneurysm size. Indeed, advances in three-dimensional visualization tools may render radiographs redundant, and its traditional role as an adjunct

examination to CTA should be carefully re-evaluated.

Summary

EVAR is a revolutionary technique that irrefutably altered the approach to AAA management. Appropriate patient selection through thorough preprocedural CT evaluation is paramount to a successful EVAR. Since its use was first reported, there has been ongoing research to investigate its efficacy and complications. In addition, EVAR may be a more costly procedure than open repair owing to a higher rate of reintervention and a need for lifelong surveillance. How to deliver care without placing an unrealistic financial burden on society is another important consideration when evaluating each imaging modality.

It is clear that EVAR is a much safer procedure than conventional open repair for treatment of AAAs. As a consequence of its low operative mortality rate, the role of early EVAR in treating relatively small aneurysms, defined as 4-5 cm, is also being assessed. Early data from the PIVOTAL (Positive Impact of Endovascular Options for treating Aneurysms Early) trial suggest beneficial effects from early treatment of small aneurysms by EVAR, providing up to 3 years of protection from rupture. However, recent data also suggest that early EVAR for AAAs <5.5 cm is not likely to be cost-effective compared to elective repair at 5.5 cm. Furthermore, two large multicenter studies comparing EVAR to open repair have shown that EVAR has a lower rate of operative mortality but a higher rate of graft-related complications, resulting in similar rates of survival for the two procedures.

- Despite its high success rate, complications of EVAR remain frequent and require monitoring. The most common among these complications are endoleaks, with the majority present on the initial post-EVAR examination. Proper classification of endoleaks is important for subsequent management.
- Although multiple imaging modalities are available for follow-up, there is currently no available ideal stand-alone imaging modality, after consideration is given to their safety profiles, availability, reproducibility, accuracy, and cost.
- CTA is a highly accurate method for detecting endoleak, but no consensus has been reached on an optimal protocol, and it also involves using ionizing radiation and potentially nephrotoxic contrast agents.
- Color Doppler US is safe, but special expertise is needed to perform and interpret imaging after EVAR for endoleak and sac morphology. It is also less accurate than CT/CTA, and less reproducible, especially in large patients.
- MRI/MRA may be a viable alternative to CT in select patients with favorable stent composition and geometry, but its cost and relative lack of availability may be prohibitive for wide acceptance at this time.
- Ultimately, the imaging solution to EVAR follow-up is likely not going to rest on one single modality. Further investigation is needed for patient risk stratification. Appropriate imaging protocols involving combinations of various imaging modalities can then be optimized for each patient subset.

Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (i.e., <30 mL/min/1.73 m^2), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73 m^2. For more information, see the American College of Radiology (ACR) Manual on Contrast Media (see the "Availability of Companion Documents" field.)

Abbreviations

- 3D, 3-dimensional
- AAA, abdominal aortic aneurysm
- CO_2, carbon dioxide
- CT, computed tomography
- CTA, computed tomography angiography
- DSA, digital subtraction angiography
- EVAR, endovascular aneurysm repair
- MRI, magnetic resonance imaging
- MRA, magnetic resonance angiography
- US, ultrasound

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."		

Clinical Algorithm(s)

Algorithms were not developed from criteria guidelines.

Scope

Disease/Condition(s)

Abdominal aortic aneurysm (AAA)

Guideline Category

Evaluation

Management

Screening

Clinical Specialty

Family Practice

Internal Medicine

Radiology

Surgery

Intended Users

Health Plans

Hospitals

Managed Care Organizations

Physicians

Utilization Management

Guideline Objective(s)

To evaluate the appropriateness of radiologic examinations for interventional planning and follow-up of abdominal aortic aneurysm (AAA)

Target Population

Patients with an abdominal aortic aneurysm

Interventions and Practices Considered

1. Computed tomography angiography (CTA)
    - Abdomen and pelvis with contrast
    - Chest, abdomen, pelvis with contrast
2. Computed tomography (CT)
    - Abdomen and pelvis without contrast
    - Chest, abdomen, pelvis without contrast
3. Magnetic resonance angiography (MRA)
    - Abdomen and pelvis without and with contrast
    - Chest, abdomen, pelvis without and with contrast
    - Chest, abdomen, pelvis without contrast
    - Abdomen and pelvis without contrast
4. Digital subtraction angiography (DSA) aorta
5. Ultrasound (US) aorta abdomen with Doppler
6. X-ray
    - Chest, abdomen, pelvis
    - Abdomen and pelvis

Major Outcomes Considered

Utility of radiologic examinations in interventional planning and follow-up of abdominal aortic aneurysm

Methodology

Methods Used to Collect/Select the Evidence

Searches of Electronic Databases

Description of Methods Used to Collect/Select the Evidence

Literature Search Procedure

The Medline literature search is based on keywords provided by the topic author. The two general classes of keywords are those related to the condition (e.g., ankle pain, fever) and those that describe the diagnostic or therapeutic intervention of interest (e.g., mammography, MRI).

The search terms and parameters are manipulated to produce the most relevant, current evidence to address the American College of Radiology Appropriateness Criteria (ACR AC) topic being reviewed or developed. Combining the clinical conditions and diagnostic modalities or therapeutic procedures narrows the search to be relevant to the topic. Exploding the term "diagnostic imaging" captures relevant results for diagnostic topics.

The following criteria/limits are used in the searches.

1. Articles that have abstracts available and are concerned with humans.
2. Restrict the search to the year prior to the last topic update or in some cases the author of the topic may specify which year range to use in

the search. For new topics, the year range is restricted to the last 5 years unless the topic author provides other instructions.
3. May restrict the search to Adults only or Pediatrics only.
4. Articles consisting of only summaries or case reports are often excluded from final results.

The search strategy may be revised to improve the output as needed.

Number of Source Documents

The total number of source documents identified as the result of the literature search is not known.

Methods Used to Assess the Quality and Strength of the Evidence

Weighting According to a Rating Scheme (Scheme Given)

Rating Scheme for the Strength of the Evidence

Strength of Evidence Key

Category 1 - The conclusions of the study are valid and strongly supported by study design, analysis, and results.

Category 2 - The conclusions of the study are likely valid, but study design does not permit certainty.

Category 3 - The conclusions of the study may be valid but the evidence supporting the conclusions is inconclusive or equivocal.

Category 4 - The conclusions of the study may not be valid because the evidence may not be reliable given the study design or analysis.

Methods Used to Analyze the Evidence

Review of Published Meta-Analyses

Systematic Review with Evidence Tables

Description of the Methods Used to Analyze the Evidence

The topic author drafts or revises the narrative text summarizing the evidence found in the literature. American College of Radiology (ACR) staff draft an evidence table based on the analysis of the selected literature. These tables rate the strength of the evidence for all articles included in the narrative text.

The expert panel reviews the narrative text, evidence table, and the supporting literature for each of the topic-variant combinations and assigns an appropriateness rating for each procedure listed in the table. Each individual panel member forms his/her own opinion based on his/her interpretation of the available evidence.

More information about the evidence table development process can be found in the ACR Appropriateness Criteria® Evidence Table Development document (see the "Availability of Companion Documents" field).

Methods Used to Formulate the Recommendations

Expert Consensus (Delphi)

Description of Methods Used to Formulate the Recommendations

Modified Delphi Technique

The appropriateness ratings for each of the procedures included in the Appropriateness Criteria topics are determined using a modified Delphi methodology. A series of surveys are conducted to elicit each panelist's expert interpretation of the evidence, based on the available data, regarding the appropriateness of an imaging or therapeutic procedure for a specific clinical scenario. American College of Radiology (ACR) staff distributes surveys to the panelists along with the evidence table and narrative. Each panelist interprets the available evidence and rates each procedure. The surveys are completed by panelists without consulting other panelists. The ratings are a scale between 1 and 9, which is further divided into three categories: 1, 2, or 3 is defined as "usually not appropriate"; 4, 5, or 6 is defined as "may be appropriate"; and 7, 8, or 9 is defined as "usually appropriate." Each panel member assigns one rating for each procedure per survey round. The surveys are collected and the results are tabulated, de-identified and redistributed after each round. A maximum of three rounds are conducted. The modified Delphi technique enables each panelist to express individual interpretations of the evidence and his or her expert opinion without excessive bias from fellow panelists in a simple, standardized and economical process.

Consensus among the panel members must be achieved to determine the final rating for each procedure. Consensus is defined as eighty percent (80%) agreement within a rating category. The final rating is determined by the median of all the ratings once consensus has been reached. Up to three rating rounds are conducted to achieve consensus.

If consensus is not reached, the panel is convened by conference call. The strengths and weaknesses of each imaging procedure that has not reached consensus are discussed and a final rating is proposed. If the panelists on the call agree, the rating is accepted as the panel's consensus. The document is circulated to all the panelists to make the final determination. If consensus cannot be reached on the call or when the document is circulated, "No consensus" appears in the rating column and the reasons for this decision are added to the comment sections.

Rating Scheme for the Strength of the Recommendations

Not applicable

Cost Analysis

The guideline developers reviewed published cost analyses.

Method of Guideline Validation

Internal Peer Review

Description of Method of Guideline Validation

Criteria developed by the Expert Panels are reviewed by the American College of Radiology (ACR) Committee on Appropriateness Criteria.

Evidence Supporting the Recommendations

Type of Evidence Supporting the Recommendations

The recommendations are based on analysis of the current literature and expert panel consensus.

Benefits/Harms of Implementing the Guideline Recommendations

Potential Benefits

Selection of appropriate radiologic imaging procedures for interventional planning and follow-up of abdominal aortic aneurysm (AAA)

Potential Harms

- Disadvantages of computed tomography angiography (CTA) include its use of ionizing radiation and contrast medium and its higher cost compared to ultrasound.
- The disadvantages of magnetic resonance imaging/angiography (MRI/MRA) include its cost, relative inaccessibility, long scanning time, patient claustrophobia, and decreased spatial resolution. Additionally, susceptibility artifact from the stent graft presents a diagnostic challenge for assessing device integrity, and may mimic graft stenosis.
- Patients with nitinol stents are the best candidates for magnetic resonance angiography (MRA), and those with stainless steel or elgiloy stents may experience significant artifacts that compromise visualization of the stent lumen and limit morphological resolution of stent wall. However, artifacts may arise even with nitinol stents secondary to stent geometry.

Gadolinium-based Contrast Agents

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (i.e., <30 mL/min/1.73 m^2), and almost never in other patients. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73 m^2. For more information, see the American College of Radiology (ACR) Manual on Contrast Media (see the "Availability of Companion Documents" field.)

Relative Radiation Level (RRL)

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults. Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document (see the "Availability of Companion Documents" field).

Contraindications

Contraindications

- While not an absolute contraindication to endovascular aneurysm repair (EVAR), mural thrombus and atherosclerotic calcification covering more than 90 degrees of the circumference of the aortic diameter in the proximal neck is associated with a higher risk for type I endoleak and stent-graft migration.
- Magnetic resonance imaging/angiography (MRI/MRA) is contraindicated in patients with cardiac pacemakers.
- Severe renal impairment and life-threatening contrast allergy are contraindications to iodinated contrast.

Qualifying Statements

Qualifying Statements

The American College of Radiology (ACR) Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection

of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the U.S. Food and Drug Administration (FDA) have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.

Implementation of the Guideline

Description of Implementation Strategy

An implementation strategy was not provided.

Institute of Medicine (IOM) National Healthcare Quality Report Categories

IOM Care Need

Getting Better

Living with Illness

IOM Domain

Effectiveness

Identifying Information and Availability

Bibliographic Source(s)

Francois CJ, Kramer JH, Rybicki FJ, Ray CE Jr, Bandyk DF, Burke CT, Dill KE, Gerhard-Herman MD, Hanley M, Hohenwalter EJ, Mohler ER III, Rochon PJ, Schenker MP, Expert Panel on Vascular Imaging and Interventional Radiology. ACR Appropriateness CriteriaÂ® abdominal aortic aneurysm: interventional planning and follow-up. [online publication]. Reston (VA): American College of Radiology (ACR); 2012. 8 p. [71 references]

Adaptation

Not applicable: The guideline was not adapted from another source.

Date Released

2010 (revised 2012)

Guideline Developer(s)

American College of Radiology - Medical Specialty Society

Source(s) of Funding

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Guideline Committee

Committee on Appropriateness Criteria, Expert Panel on Vascular Imaging and Interventional Radiology

Composition of Group That Authored the Guideline

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Financial Disclosures/Conflicts of Interest

Not stated

Guideline Status

This is the current release of the guideline.

This guideline updates a previous version: Lin M, Narra VR, Rybicki FJ, Funaki BS, Burke CT, Fan CM, Gerhard-Herman MD, Kim HS, Koss SA, Mansour MA, Owens CA, Ray CE Jr, Saad WEA, Expert Panel on Vascular Imaging and Interventional Radiology. ACR Appropriateness Criteria® abdominal aortic aneurysm: interventional planning and follow-up. [online publication]. Reston (VA): American College of Radiology (ACR); 2010. 8 p.

Guideline Availability

Electronic copies: Available from the American College of Radiology (ACR) Web site.

Print copies: Available from the American College of Radiology, 1891 Preston White Drive, Reston, VA 20191. Telephone: (703) 648-8900.

Availability of Companion Documents

The following are available:

- ACR Appropriateness Criteria®. Overview. Reston (VA): American College of Radiology; 2 p. Electronic copies: Available in Portable Document Format (PDF) from the American College of Radiology (ACR) Web site.
- ACR Appropriateness Criteria®. Literature search process. Reston (VA): American College of Radiology; 1 p. Electronic copies: Available in PDF from the ACR Web site.
- ACR Appropriateness Criteria®. Evidence table development – diagnostic studies. Reston (VA): American College of Radiology; 2013 Nov. 3 p. Electronic copies: Available in PDF from the ACR Web site.
- ACR Appropriateness Criteria®. Evidence table development – therapeutic studies. Reston (VA): American College of Radiology; 2013 Nov. 4 p. Electronic copies: Available in PDF from the ACR Web site.
- ACR Appropriateness Criteria®. Radiation dose assessment introduction. Reston (VA): American College of Radiology; 3 p. Electronic copies: Available in PDF from the ACR Web site.
- ACR Appropriateness Criteria®. Manual on contrast media. Reston (VA): American College of Radiology; 90 p. Electronic copies: Available in PDF from the ACR Web site.
- ACR Appropriateness Criteria®. Procedure information. Reston (VA): American College of Radiology; 1 p. Electronic copies: Available in

PDF from the ACR Web site .

- ACR Appropriateness Criteria® abdominal aortic aneurysm: interventional planning and follow-up. Evidence table. Reston (VA): American College of Radiology; 2012. 36 p. Electronic copies: Available in PDF from the ACR Web site .

Patient Resources

None available

NGC Status

This summary was completed by ECRI Institute on September 8, 2011. This summary was updated by ECRI Institute on April 17, 2013.

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